Paysage International des Recherches en Géomatique

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Séminaire syllabus

Développement historique et principales avancées

Tendances théoriques et méthodologiques

Enjeux de recherche

Apports possibles pour les sciences environnementales et urbaines

Géomatique vs GIScience

La **géomatique** est une discipline regroupant les pratiques, méthodes et technologies qui permettent de collecter, analyser et diffuser des données géographiques

GIScience is the scientific discipline that studies data structures and computational techniques to capture, represent, process, and analyze geographic information

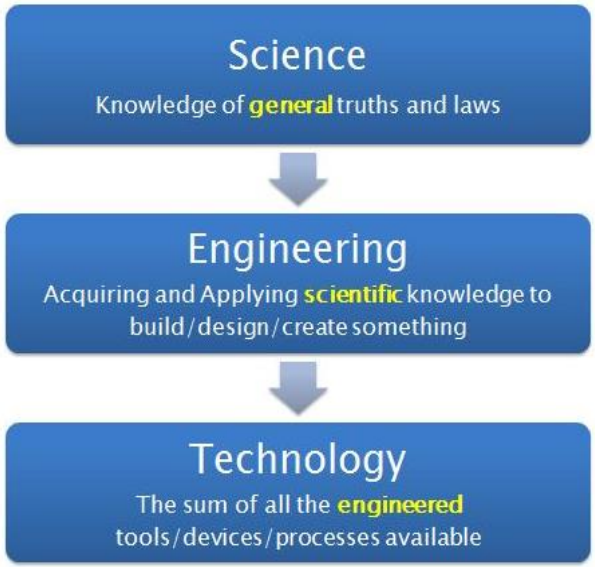
Géomatique vs GIScience & others…

Descriptive term	Number of entries in WoS
Cybercartography	2
Geospatial Technologies	56
Geocomputation	24
Computer Cartography	25
Geomatics	79
Geoinformation	103
Geoinformatics	31
GIScience	128
Spatial Information Technology	26
Spatial Information Science	10

Géomatique vs GIScience & others…

geomatics	*geoinformatics*	*giscience*
Canada (30)	USA (9)	USA (72)
USA (14)	Germany (6)	England (18)
Australia (8)	India (4)	Germany (9)
England (7)	Russia (3)	Canada (8)
Peoples R China (4)	Sweden (3)	Peoples R China (7)

Science vs technology ?



General view: theoretical science gives rise to technical applications

Science -> Technology

Could GIScience be described as a history of a technology turning into a science ? GIS systems -> GIS science

“Whereas scientists study the world, technologists help alter it–for better or worse. Shorter: Science is about truth, technology is about utility”
(Bunge, 2007)

Science vs technology ?

GIS science is supposed to be the theoretical underpinnings of GISystems, which in turn, is presented as its application

This distinction between theoretical and applied science is a distinction between science and technology

The distinction is hierarchical with science on top of technology

Science vs technology ?

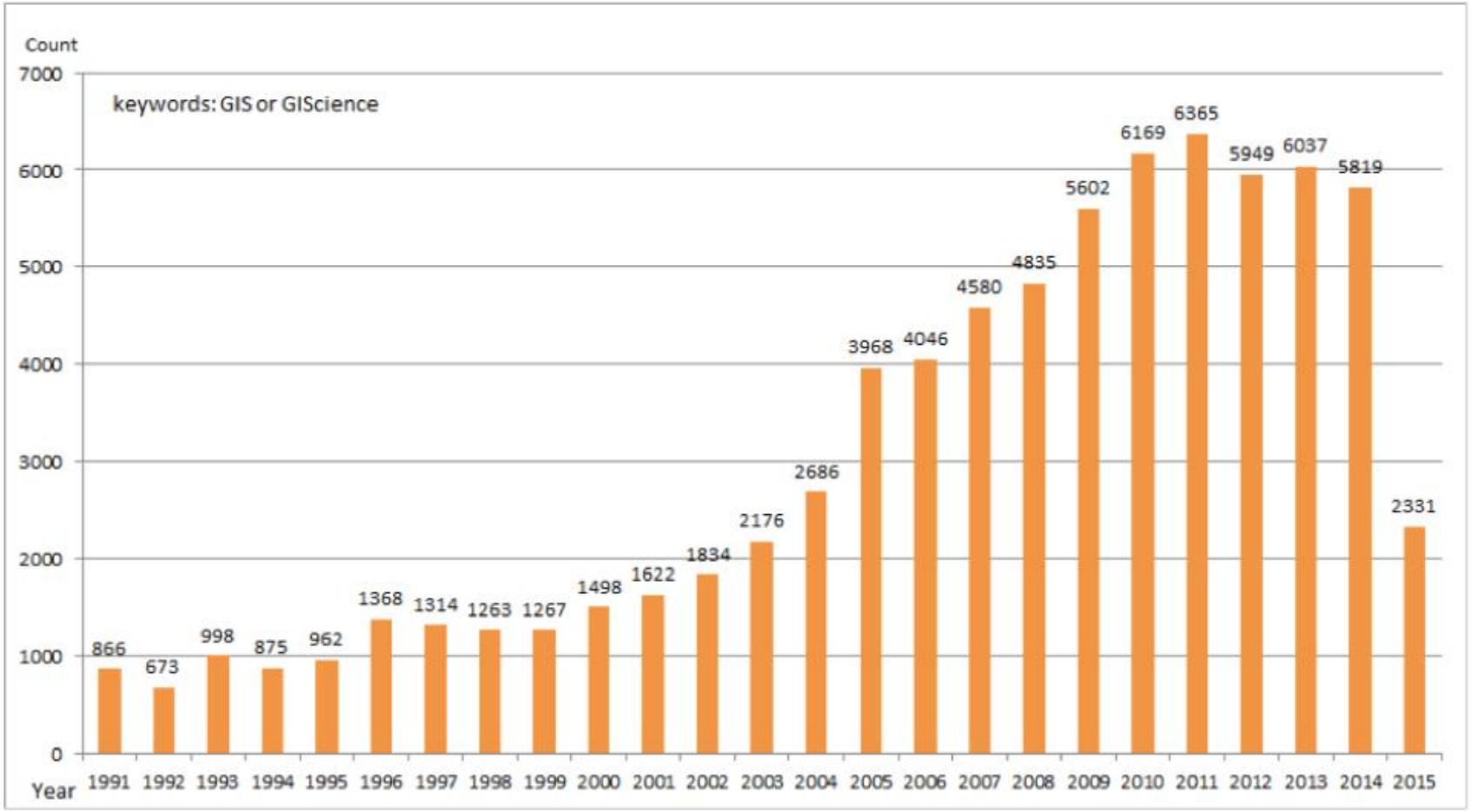
"GIScience should study the fundamental issues arising from geographic information (Longley et al., 2005)

"GIScience provides the basic intellectual underpinnings for geographic information technologies, and GIScience research should be supported at levels appropriate to the importance of these technologies and their application (Mark, 1999)"

Science vs technology ?

“Since GIScience 2006 focuses on advances in the fundamentals of Geographic Information Science, submission of GIS application papers is discouraged” !

Retrieved, 31/8 2006 from http://www.giscience.org/submissions.php



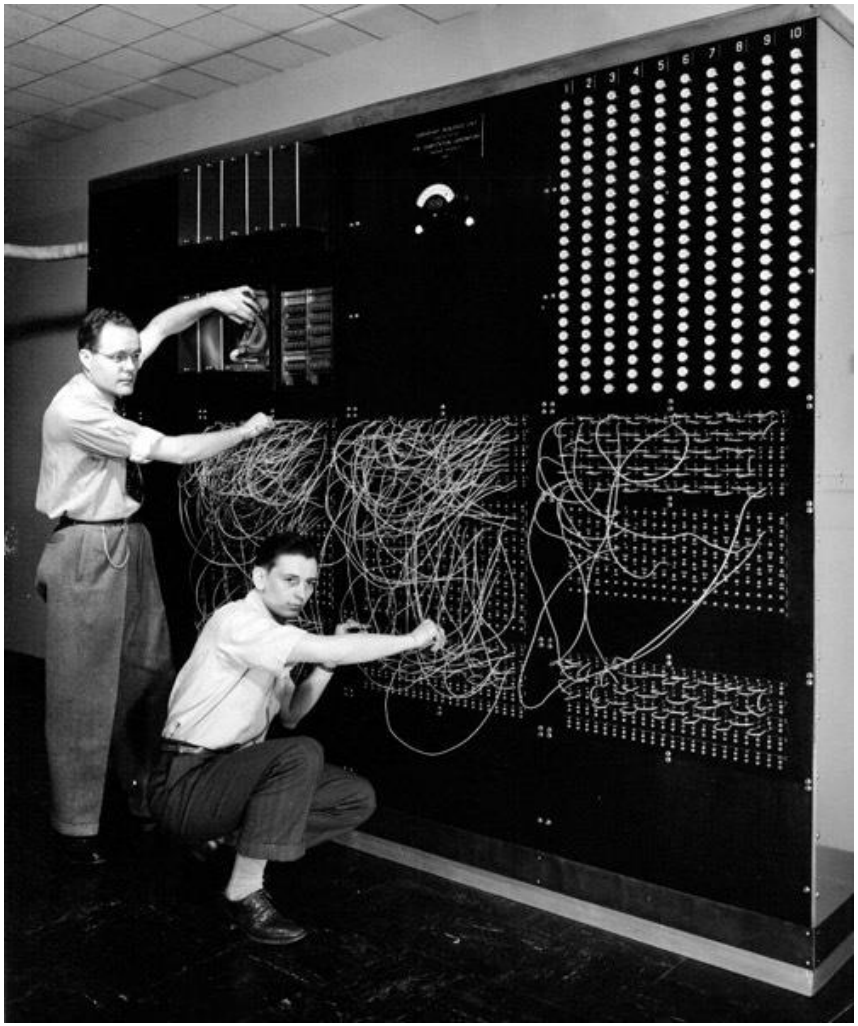
Total number of publications with the keywords GIS or GIScience, from a Scopus query for the years 1991 through 2015, executed in July 2015

Be aware…

GIS must be taken seriously as a science in academia, by a group of disciplines with common interests. Without such arguments, the GIS field will fragment, and the GIS storm will blow itself out

Note that the field is small ! Rhetoric about in the industry aside, no one would suggest that the field of GIS is a major discipline

Let us
come back
to the early
days…



The early days

Roger Tomlinsom's first Canadian Land Inventory

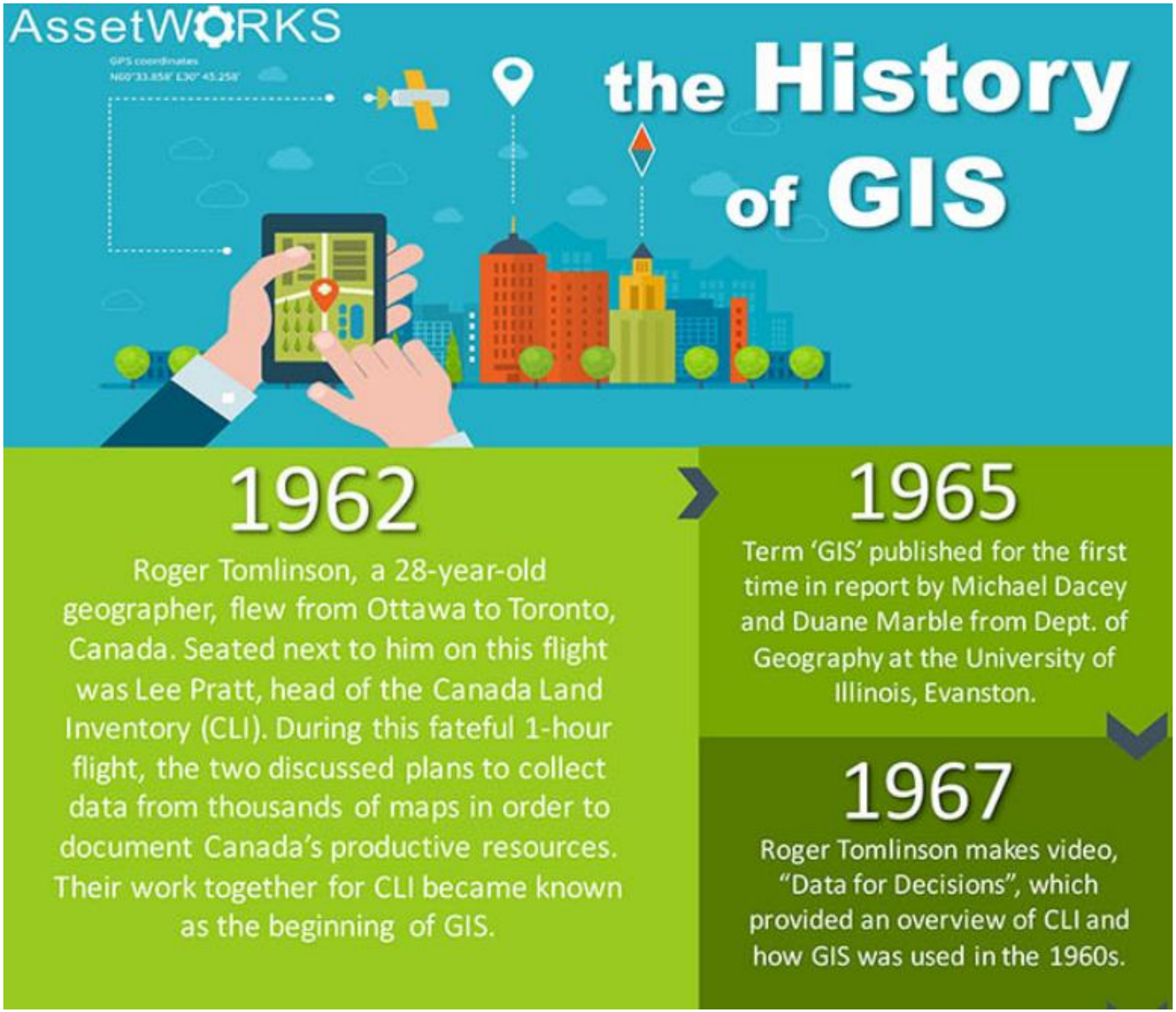
"Computer Mapping: An Introduction to the Use of Electronic Computers in the Storage, Compilation and Assessment of Natural and Economic Data for the Evaluation of Marginal Lands" (National Land Capability Inventory Seminar, Ottawa, November 1962)

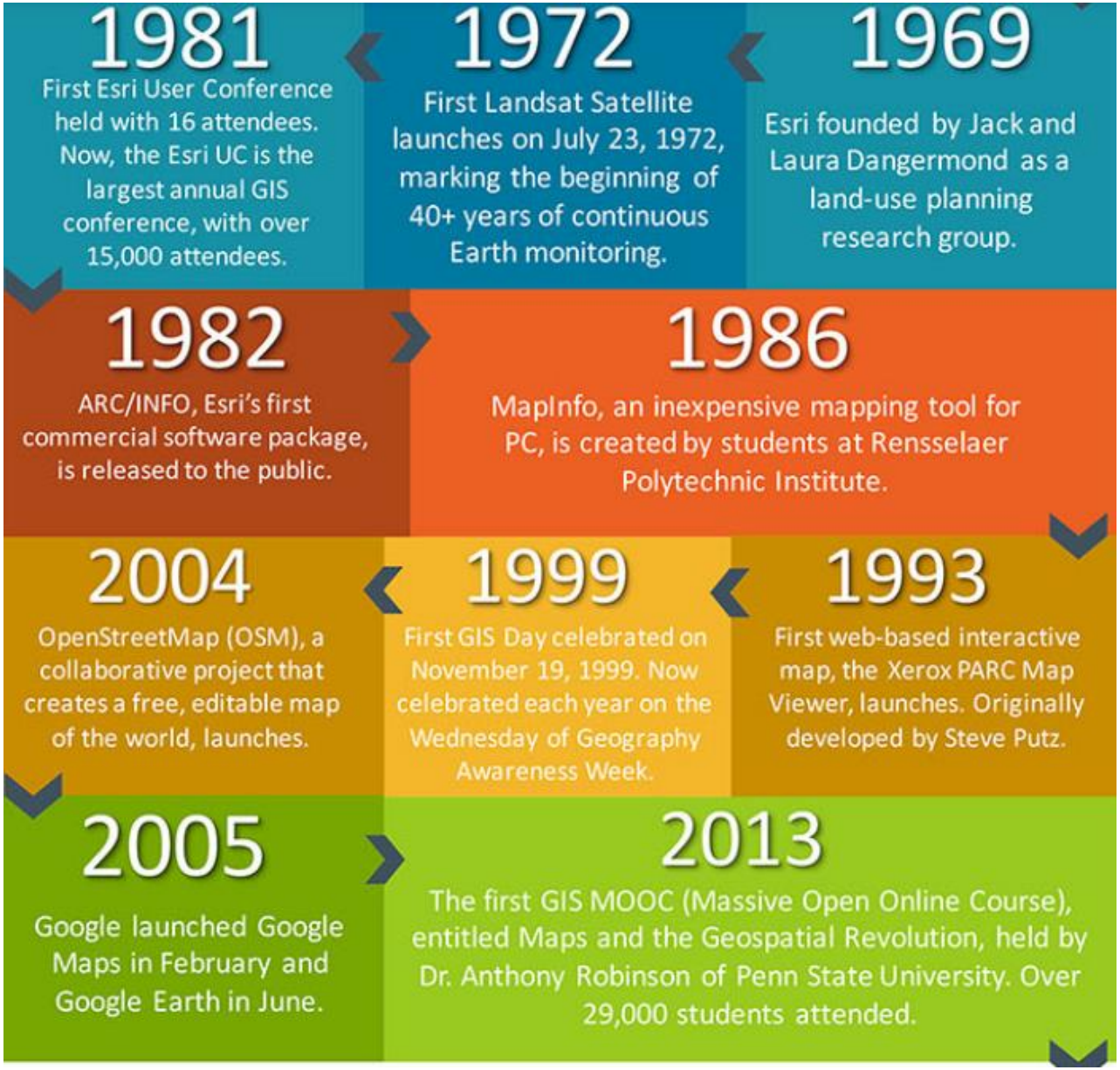
A Geographic Information System for Regional Planning (CSIRO Symposium, 1968)

On the History of GIS

First contribution:

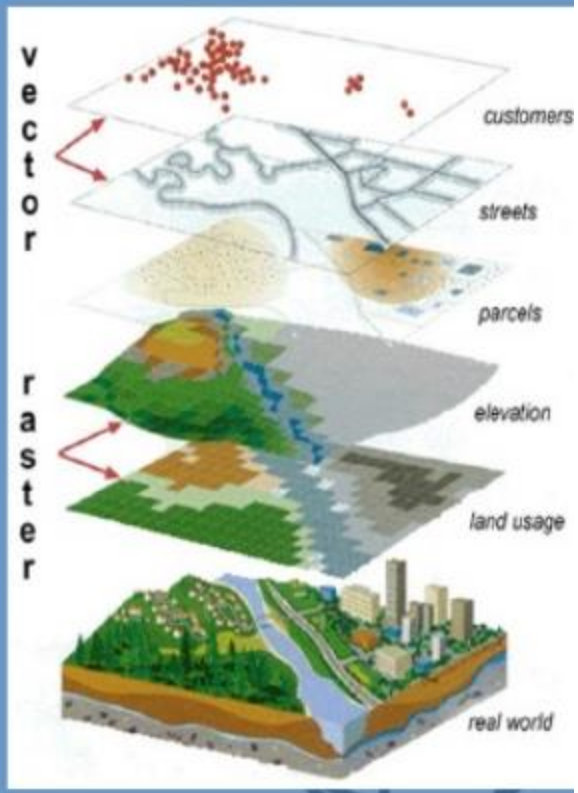
Maguire, D. J., Goodchild, M.F. & Rhind, D. W., Eds., Geographical Information Systems: Principles and Applications, Longman, 1991.


AssetWORKS
the History of GIS
1962
Roger Tomlinson, a 28-year-old geographer, flew from Ottawa to Toronto, Canada. Seated next to him on this flight was Lee Pratt, head of the Canada Land Inventory (CLI). During this fateful 1-hour flight, the two discussed plans to collect data from thousands of maps in order to document Canada's productive resources. Their work together for CLI became known as the beginning of GIS.
1965
Term 'GIS' published for the first time in report by Michael Dacey and Duane Marble from Dept. of Geography at the University of Illinois, Evanston.
1967
Roger Tomlinson makes video, "Data for Decisions", which provided an overview of CLI and how GIS was used in the 1960s.


1981
First Esri User Conference held with 16 attendees. Now, the Esri UC is the largest annual GIS conference, with over 15,000 attendees.
1972
First Landsat Satellite launches on July 23, 1972, marking the beginning of 40+ years of continuous Earth monitoring.
1969
Esri founded by Jack and Laura Dangermond as a land-use planning research group.
1982
ARC/INFO, Esri's first commercial software package, is released to the public.
1986
MapInfo, an inexpensive mapping tool for PC, is created by students at Rensselaer Polytechnic Institute.
2004
OpenStreetMap (OSM), a collaborative project that creates a free, editable map of the world, launches.
1999
First GIS Day celebrated on November 19, 1999. Now celebrated each year on the Wednesday of Geography Awareness Week.
1993
First web-based interactive map, the Xerox PARC Map Viewer, launches. Originally developed by Steve Putz.
2005
Google launched Google Maps in February and Google Earth in June.
2013
The first GIS MOOC (Massive Open Online Course), entitled Maps and the Geospatial Revolution, held by Dr. Anthony Robinson of Penn State University. Over 29,000 students attended.

On the History of GIS: the Software Perspective

- 1962: Creation of first modern GIS computer system, CGIS
- 1964: Harvard Laboratory begins development general-purpose mapping software (SYMAP)
- 1969: ESRI founded, inspired by Harvard's software
- 1982: ESRI releases ARC/INFO
- 1992: ESRI releases ArcView



GIS Research: the Starting Days

The NCGIA Initiatives

Abler, R. F. The National Science Foundation National Center for Geographic Information and Analysis. International Journal of Geographical Information System 1, 4 (1987) 303–326..

NCGIA Initiatives (1988-1996)

National Center for Geographic Information and Analysis

1: Accuracy of Spatial Databases
2: Languages of Spatial Relations
3: Multiple Representations
4: Use and Value of Geographic Information
5: Architecture of Very Large Spatial Databases
6: Spatial Decision Support systems
7: Visualizing the Quality of Spatial Information
8: Formalizing Cartographic Knowledge
9: Institutions Sharing Geographic Information
10: Spatio-temporal Reasoning in GIS
12: Integration of Remote Sensing and GIS
13: User Interfaces for GIS
14: Spatial Analysis
16: Law, Information Policy and Spatial Databases
17: Collaborative Spatial Decision Making
19: Social aspects in GIS
20: Interoperating GIS
21: Formal Models for Common Sense Geographic words

More at http://www.ncgia.ucsb.edu/

Main GIS priorities in GIS research

Goodchild (IJGIS, 1992)

- Data collection and measurement
- Data capture
- Spatial statistics
- Data modeling and theories of spatial data
- Data structures, algorithms, and processes
- Display
- Analytical tools
- Institutional, managerial, and ethical issues

Main GIS priorities in GIS research

UCGIS (1996)

Spatial data acquisition and integration
Distributed computing
Extensions to geographic representations
Cognition of geographic information
Spatial analysis in a GIS environment
Future of the spatial information infrastructure
Uncertainty in spatial data
Interoperability of geographic information Scale
GIS and society

Main GIS priorities in GIS research

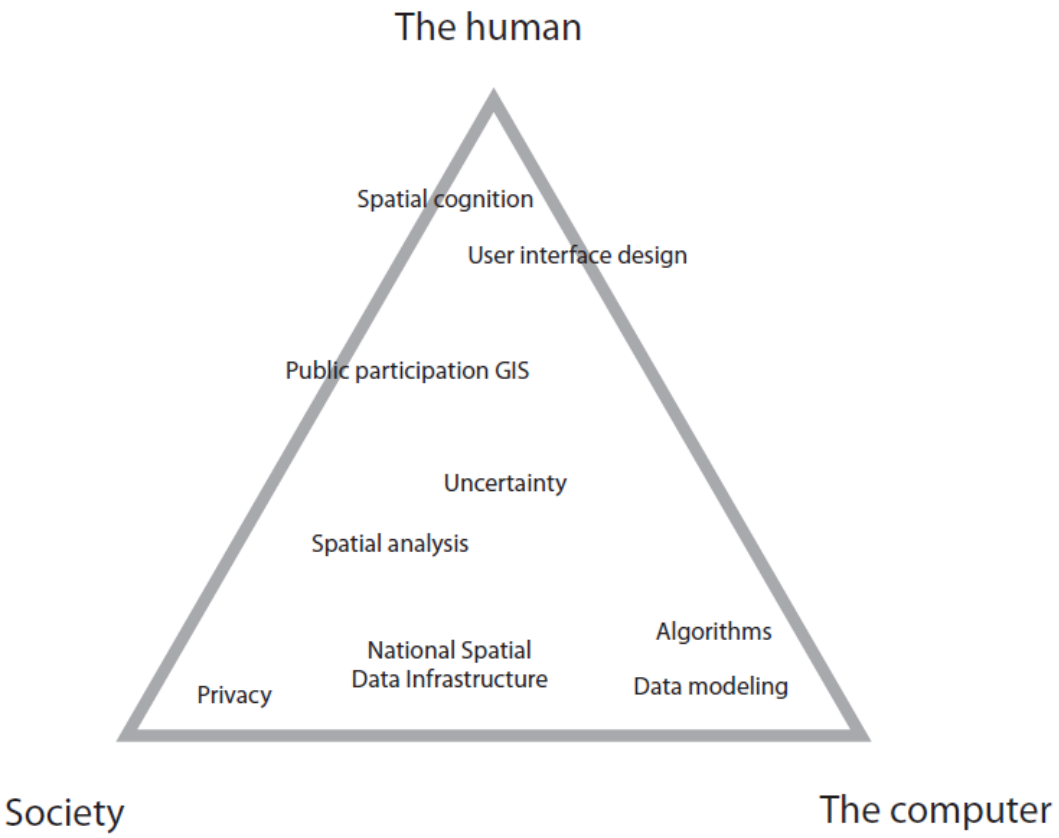
European Agile Agenda (1998)

- Environmental modelling
- GI Education
- Interoperability
- Data policy

Varenius (1999)

- Cognitive models of geographic space
- Computational methods for geographic concepts
- Geographies of the information society

Varenius conceptual framework for GIScience



Canadian GEOIDE Research Network (1998-2012)

Priority areas: Mobility, Environmental Change, Sensors

Tab. 1. The disciplines involved at Phase III (2008)

Departmental affiliation of Network Investigators (Phase III)	Number of researchers	% of total
Geomatics	23	17.3
Geography	19	14.3
Earth Science (Geology, Geophysics, Atmospheric Sciences)	19	14.3
Civil and other Engineering	18	12.8
Computer Science	12	9.0
Statistics (Mathematics)	9	6.8
Environmental Studies (Biology, Landscape Ecology, Ocean)	8	6.0
Forestry	6	4.5
Medicine (with Public Health, Kinesiology)	6	4.5
Physics	5	3.8
Planning (with Landscape Architecture)	4	3.0
Archaeology	3	2.3
Business	2	1.5

Canadian GEOIDE Research Network (1998-2012)

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Environmental Studies (Biology, Landscape Ecology, Ocean)	8	6.0
Forestry	6	4.5
Medicine (with Public Health, Kinesiology)	6	4.5
Physics	5	3.8
Planning (with Landscape Architecture)	4	3.0
Archaeology	3	2.3
Business	2	1.5

Canadian GEOIDE Research Network (1998-2012)

MCMaster et al (2004)

- Geographic visualization
- Ontological foundations for GIScience
- Remotely acquired data and information in GIScience
- Geospatial data mining and knowledge discovery

Egenhofer et al. (2015)

- Ontologies in GIS
- Volunteered GIS
- Spatial big data
- Cyber GIS

UN-GGIM main research & development priorities

1. Development of the global geodetic reference frame
2. Development of a global map for sustainable development
3. Geospatial information supporting Sustainable Development and post 2015 dpt agenda
4. Adoption and implementation of standards by the global GI community
5. Development of a knowledge base for geospatial information
6. Identification of trends in national institutional arrangements in GI management
7. Integrating geospatial statistics and other information
8. Legal and policy frameworks, including critical issues related to authoritative data
9. Development of shared statement of principles on the management of GI
10. Determining fundamental data sets

The French view…

Priorités GDR MAGIS 1992-1995

Thématiques

SIG multi-dimensionnels

SIG multi-échelles

SIG qualité et enrichissement

SIG images, raisonnement symbolique et numérique

Priorités GDR MAGIS 1996-1999

Thématiques

Temps et Qualité des données

Analyse spatiale

Communication et coopération

Priorités GDR MAGIS 2001-2004

Thématiques

Gestion de l'environnement

Analyse spatiale

Qualité

Interactions

SIG et mobilités

Imagerie satellitaire et aérienne

Priorités GDR MAGIS 2005-2009

Thématiques

Echanges – construction – mutualisation

Mobilité – réactivité – temps réel

Multi-représentation

Services géo-localisés

Risques

Observation de la terre

Gouvernance des territoires

Cartographie dynamique

Priorités GDR MAGIS 2010-2015

Actions Prospectives

Ontologies Spatio-Temporelles
Incertitude Epistémique
Extraction et Recherche d'Information Géographique
Analyse d'images pour le suivi des milieux
Autour des Capteurs
Gros Volumes de Données
Cartographie et Cognition
SIG3D : La troisième dimension en Géomatique
Modélisation et analyse de la mobilité individuelle
Dynamiques Spatiales et Interactions

Thématiques

Transport et mobilité
Energie
Milieux
Usages

Any scientific commonalities ?

Are such challenges unique, or do they have something in common with other areas?

In some cases, they may not be unique; they may be common to information technology adoption/diffusion in general

Other issues do seem to be unique to GIS

Challenges that seem unique to GIS

How to model time-dependent geographic data

How to capture, store, and process three-dimensional geographical data

How to model data for geographical distributions draped over surfaces embedded in three dimensions

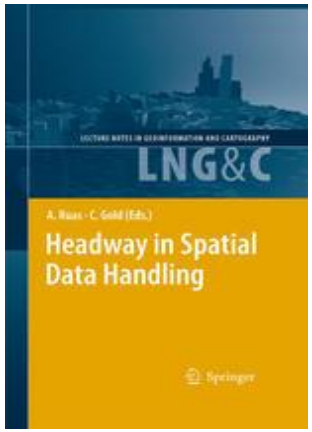
How to explore geographical data

How to evaluate the geographic perspective on information and processes relative to more conventional perspectives

Routes to innovation

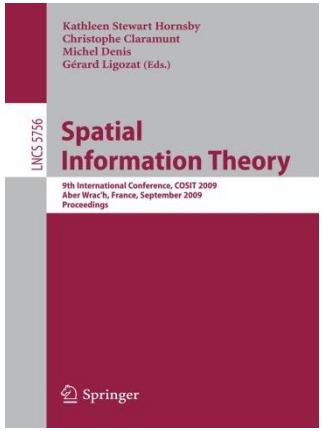
…

Established conferences



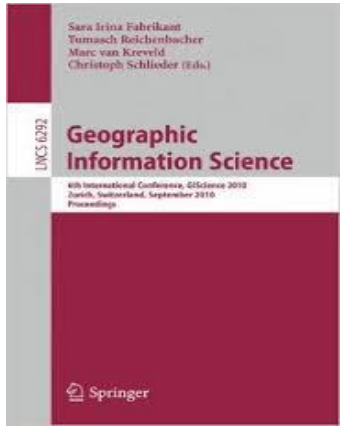
Start 1988

Start 1989



Start 1993

Start 1993

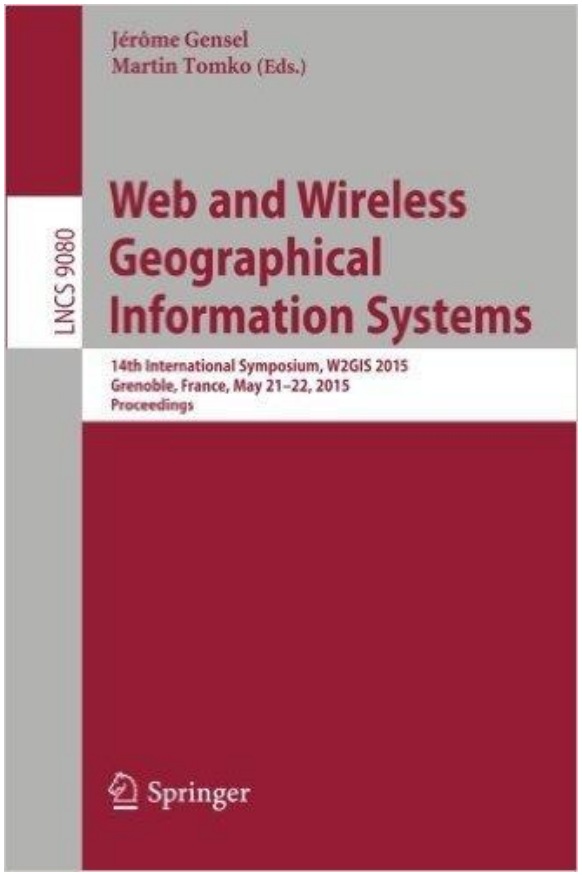


Start 2000

Start 1998

Start …

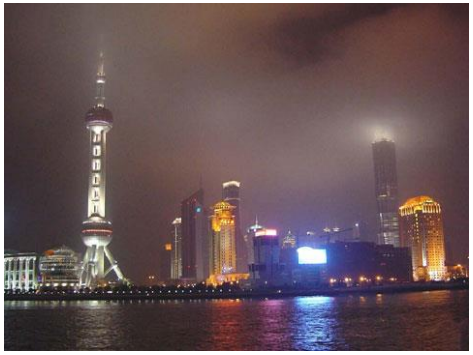
Established conferences



Advances in recent development of Web and Wireless Geographical Information Systems

(Kyoto 2001, Singapore 2002, Roma 2003, Hankuk South Korea 2004, Lausanne 2005, Hong Kong 2006, Cardiff 2007, Shanghai 2008, Dubin 2009, Kyoto 2011, Naples 2012, Banff 2013, Seoul, 2014, Grenoble 2014)

Shanghai 2017 !!!



Established GIS journals

International Journal of GIS, Taylor & Francis
http://www.tandfonline.com/toc/tgis20/current

Geoinformatica, Springer
http://link.springer.com/journal/10707

Transactions in GIS, Wiley
http://onlinelibrary.wiley.com/journal/10.1111/%28ISSN%291467-9671

Computers Environment & Urban Systems, Elsevier
http://www.journals.elsevier.com/computers-environment-and-urban-systems/

Spatial Cognition and Computation, Taylor & Francis
http://www.tandfonline.com/toc/hscc20/current

Journal of Spatial Information Science
http://www.josis.org/index.php/josis

Geographical Systems, Springer
http://www.springer.com/economics/regional+science/journal/10109

Annals of GIS, Taylor & Francis
http://www.tandfonline.com/toc/tagi20/current

Revue Internationale de Géomatique, Hermes, http://rig.revuesonline.com/

Cybergeo, https://cybergeo.revues.org/

Routes to innovation (following K. Beard)

An innovation can be considered significant based on one or more of the following criteria:

- Widely adopted;
- Led to scientific breakthroughs or benefits;
- Improved data or information understanding;

or

- Led to increased ease of use.

Major accomplishments

1987	**Openshaw, Charlton, Wymer, Craft**: A Mark I Geographical Analysis Machine for the Automated Analysis of Point Data Sets
1988	**Brassel and Weibel**: A Review and Conceptual Framework of Automated Map Generalization
1989	**Heuvelink, Burrough, and Stein**: Propagation of Errors in Spatial Modelling with GIS
1989	**Skidmore**: A Comparison of Techniques for Calculating Gradient and Aspect from a Gridded Digital Elevation Model
1990	**Worboys, Hearnshaw, Maguire**: Object-Oriented Data Modelling for Spatial Databases
1991	**Egenhofer and Franzosa**: Point-Set Topological Spatial Relations
1991	**Miller**: Modelling Accessibility Using Space-Time Prism Concepts within Geographical Information Systems
1992	**Goodchild**: Geographical Information Science
1993	**Fisher**: Algorithm and Implementation Uncertainty in Viewshed Analysis
1995	**Raper and Livingstone**: Development of a Geomorphological Spatial Model Using Object-Oriented Design
1995	**Jankowski**: Integrating Geographical Information Systems and Multiple Criteria Decision-Making Methods
1996	**Fotheringham, Charlton, Brunsdon**: The Geography of Parameter Space: An Investigation of Spatial Non-Stationarity
1996	**Frank**: Qualitative Spatial Reasoning: Cardinal Directions as an Example
1997	**Kiiveri**: Assessing, Representing, and Transmitting Positional Uncertainty in Maps
1998	**Clarke and Gaydos**: Loose-Coupling a Cellular Automaton Model and GIS: Long-Term Urban Growth Prediction for San Francisco and Washington/Baltimore
1998	**Bishr**: Overcoming the Semantic and Other Barriers to GIS Interoperability
1999	**Andrienko and Andrienko**: Interactive Maps for Visual Data Exploration
2001	**Smith and Mark**: Geographical Categories: An Ontological Investigation
2003	**Llobera**: Extending GIS-Based Visual Analysis: The Concept of Visualscapes

Table 1: The 19 papers selected by Fisher [19] as IJGIS classics.

Table 3: The ten most frequently cited articles published in the *International Journal of Geographical Information Science/Systems*, based on Google Scholar.

Title	Authors	Year published	Cited by as of August 2015
Point-set topological spatial relations	Egenhofer and Franzosa	1991	1,808
The GARP modelling system: problems and solutions to automated spatial prediction	Stockwell	1999	1,185
Integrating multi-criteria evaluation with geographical information systems	Carver	1991	891
Loose-coupling a cellular automaton model and GIS: long-term urban growth prediction for San Francisco and Washington/Baltimore	Clarke and Gaydos	1998	858
Geographical information science	Goodchild	1992	858
Kriging: a method of interpolation for geographical information systems	Oliver and Webster	1990	784
Integrating geographical information systems and multiple criteria decision-making methods	Jankowski	1995	667
GIS-based multicriteria decision analysis: a survey of the literature	Malczewski	2006	637
An event-based spatiotemporal data model (ESTDM) for temporal analysis of geographical data	Peuquet and Duan	1995	605
Interpolating mean rainfall using thin plate smoothing splines	Hutchinson	1995	551

Table 4: The ten most frequently cited articles published in *Transactions in GIS*, based on Google Scholar.

Title	Authors	Year published	Cited by as of August 2015
Using ontologies for integrated geographic information systems	Fonseca, Egenhofer, Agouris, and Câmara	2002	507
Integrating dynamic environmental models in GIS: the development of a dynamic modelling language	Wesselung, Karssenberg, Burrough , and van Deursen	1996	286
GI science, disasters, and emergency management	Cuttler	2003	226
Critical issues in participatory GIS: deconstructions, reconstructions, and new research directions	Elwood	2003	212
A new GIS-based solar radiation model and its application to photovoltaic assessments	Šúri and Hofierka	2004	202
Quality assessment of the French OpenStreetMap dataset	Girres and Touya	2010	196
On the use of weighted linear combination method in GIS: common and best practice approaches	Malczewski	2000	180
Use of information technology for community empowerment: transforming geographic information systems into community information systems	Ghose	2001	175
Integration of space syntax into GIS: new perspectives for urban morphology	Jiang and Claramunt	2002	176
Technical Note: A GIS-coupled hydrological model system for the watershed assessment of agricultural nonpoint and point sources of pollution	Di Luzio and Srinivasan	2004	165

Table 5: The ten most frequently cited papers published in the proceedings of the *Conference on Spatial Information Theory* (including COSIT 0), based on Google Scholar.

Title	Authors	Year published	Cited by as of August 2015
Using orientation information for qualitative spatial reasoning	Freksa	1992	648
Naive geography	Egenhofer and Mark	1995	600
Cognitive maps, cognitive collages, and spatial mental models	Tversky	1993	526
Scale and multiple psychologies of space	Montello	1993	416
Reasoning about gradual changes of topological relationships	Egenhofer and Al-Taha	1992	399
People manipulate objects (but cultivate fields): beyond the raster-vector debate in GIS	Couclelis	1992	389
The nature of landmarks for real and electronic spaces	Sorrows and Hirtle	1999	358
Network and psychological effects in urban movement	Hillier and Iida	2005	287
Elements of good route directions in familiar and unfamiliar environments	Lovelace, Hegarty, and Montello	1999	285
Pictorial and verbal tools for conveying routes	Tversky and Lee	1999	280

Table 6: The ten most frequently cited papers published in the fully-refereed proceedings of the *GIScience*, conference series based on Google Scholar.

Title	Authors	Year published	Cited by as of August 2015
Enriching wayfinding instructions with local landmarks	Raubal and Winter	2002	381
The SPIRIT spatial search engine: architecture, ontologies and spatial indexing	Jones, Abdelmoty, Finch, and Fu	2004	165
From objects to events: GEM, the geospatial event model	Worboys and Hornsby	2004	164
Project Lachesis: parsing and modeling location histories	Hariharan and Toyama	2004	168
Analyzing relative motion within groups oftrackable moving point objects	Laube and Imfeld	2002	125
Transmitting vector geospatial data across the Internet	Buttenfield	2002	123
Modeling the semantics of geographic categories through conceptual integration	Kuhn	2002	91
GeoVSM: An integrated retrieval model for geographic information	Cai	2002	59
Semi-automatic ontology alignment for geospatial data integration	Cruz, Sunna, and Chaudhry	2004	57
What is the region occupied by a set of points?	Galton and Duckham	2006	57

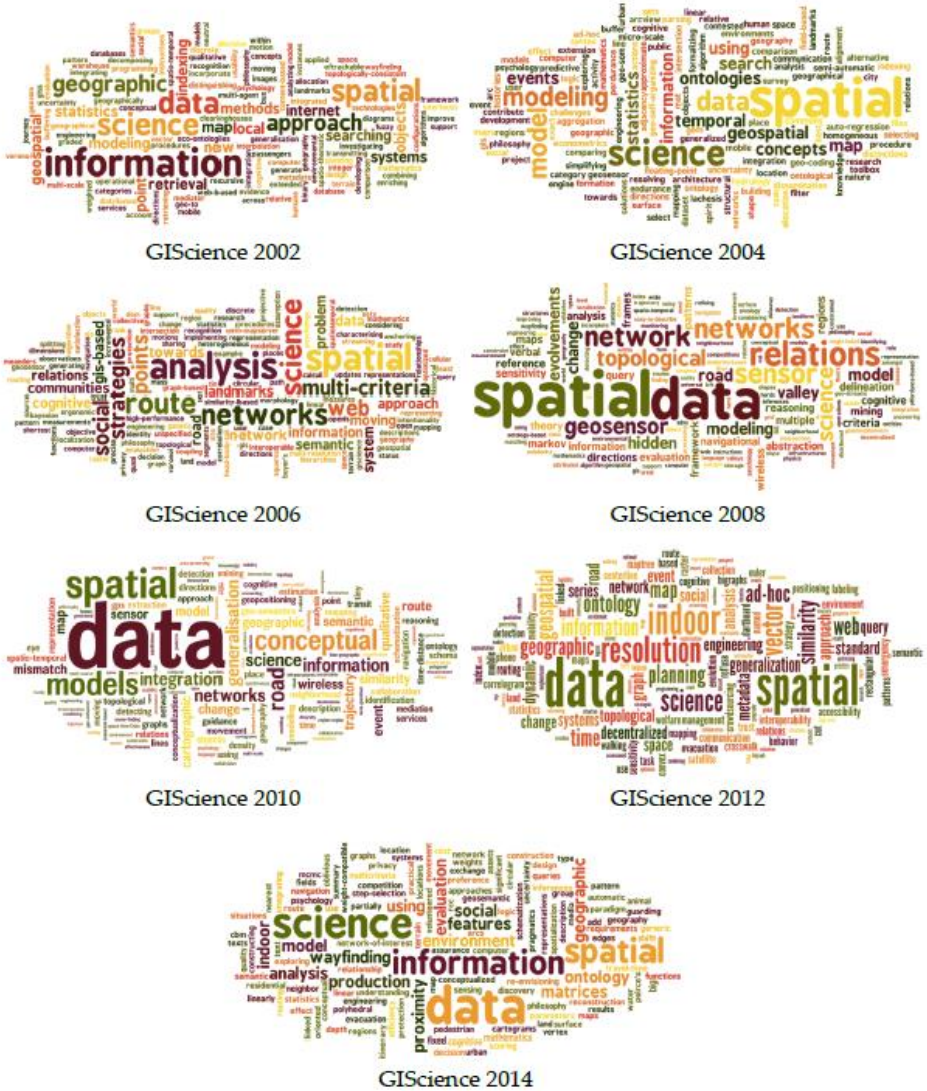


Figure 2: Word clouds of full papers of the GIScience conference 2002–2014.

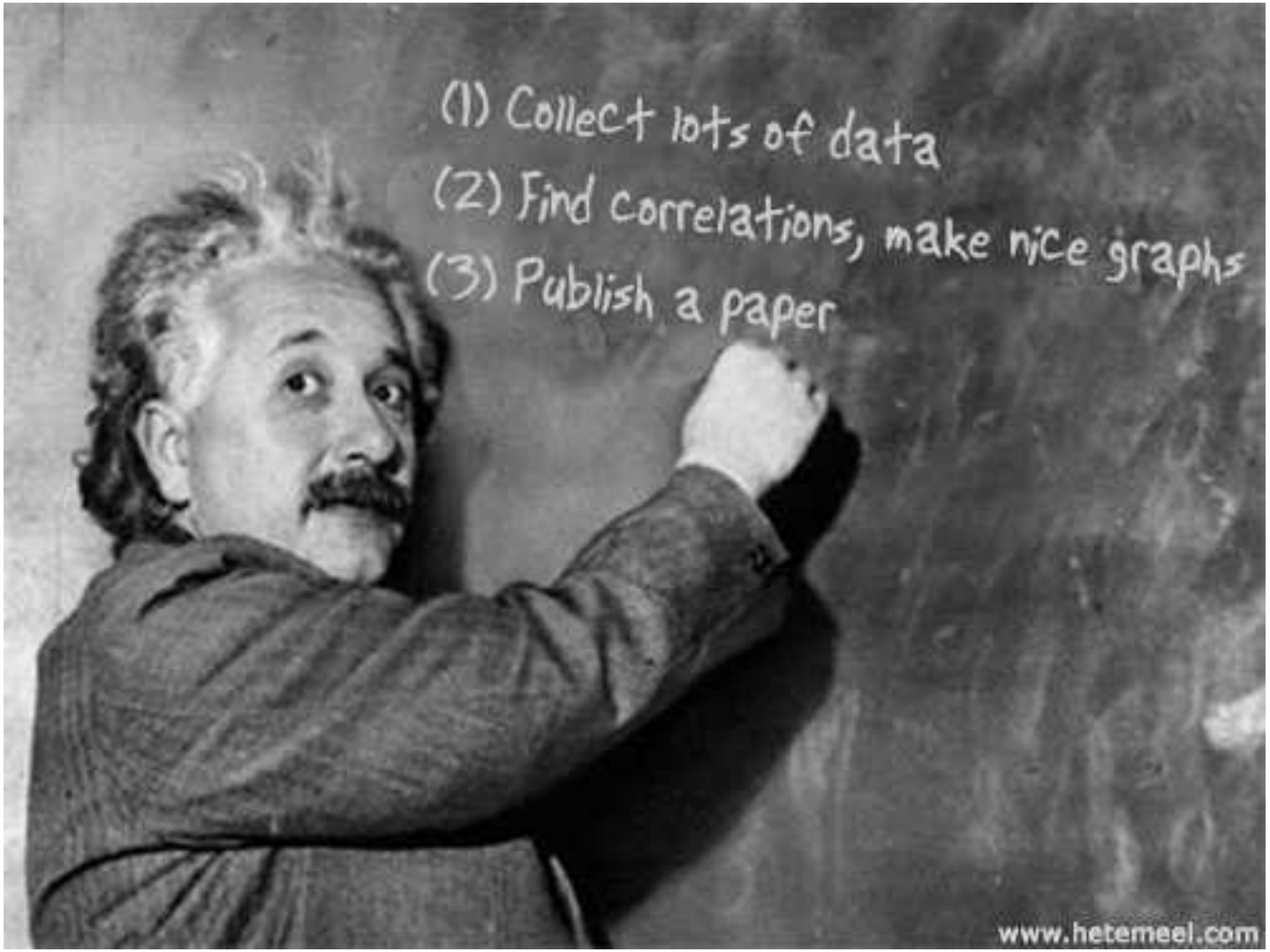
Major accomplishers

Table 2: The seventeen researchers who published at least one full paper in each of the three conference series ACM GIS, COSIT, and GIScience by 2012 [52], plus the five who joined this club by 2015.

Benjamin Adams	Krzysztof Janowicz	Andrea Rodríguez
Christophe Claramunt	Christopher B. Jones	John Stell
Matthew P. Dube	Werner Kuhn	Egemen Tanin
Matt Duckham	Lars Kulik	Jan Oliver Wallgrün
Max J. Egenhofer	Ross S. Purves	Stephan Winter
Leila De Floriani	Martin Raubal	Michael Worboys
Andrew U. Frank	Kai-Florian Richter	
Mark Gahegan	Claus Rinner	

Routes to the future…

In the era of big spatial data …



In the era of big spatial data for GIS science

Mark Gahegan (2015)….Discovery rather than theory led

Storing unprecedented volumes of data

Describing what we have in ways that are helpful to future users

Finding what we need, in the context of our current tasks

Working out what we do not need to keep

Governing data collections well, within their communities of use

www.cigi.illinois.edu/cybergis12/ppt/gahegan.ppt

In the era of big spatial data for GIS science

Create successful tools and languages to describe and find data, so that reuse is actively encouraged

Enable the analysis (re-educate to reset the expectations…)

The data that we collect forms a natural history of the changing planet on which we live (the same cannot be said for many other sciences...)

This ongoing record is more important than the individual research we each engage in (Note we may not anticipate the questions that future researchers may need to answer using our data)

www.cigi.illinois.edu/cybergis12/ppt/gahegan.ppt

Emerging Technological Trends Likely to Affect GIScience in the next 20 Years (Nittel et al., 2015)

Networked sensors and real-time GIS

Autonomous data collection & analysis

People as sensors & intuitive GIS

Geovisual analytics

Novel interfaces

Stereoscopy & 3D diplays, Head-Mounted displays, 3D walls

Mobile screens

www.spatial.maine.edu/~nittel/.../Vespucci_TechTrends_2015.pdf

Emerging Societal Challenges to impact GIScience (Couclelis et al., 2015)

Demography

Urbanization

Climate

https://www.researchgate.net/profile/Helen_Couclelis

Spatio-temporal theories and models for environmental, urban and social sciences: where do we stand ?

C. Claramunt & Kathleen Stewart, Spatial Cognition & Computation 15(2): 61-67 (2015)

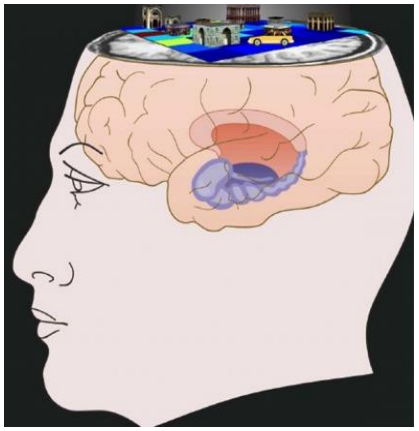
Main achievements so far

- Spatio-temporal reasoning frameworks
- Movement trajectories & activity patterns
- Events and processes
- Spatio-temporal visualization
- Spatio-temporal data mining
- Privacy issues
- Big spatio-temporal dta
- Spatio-temporal analysis with social media

Further research directions

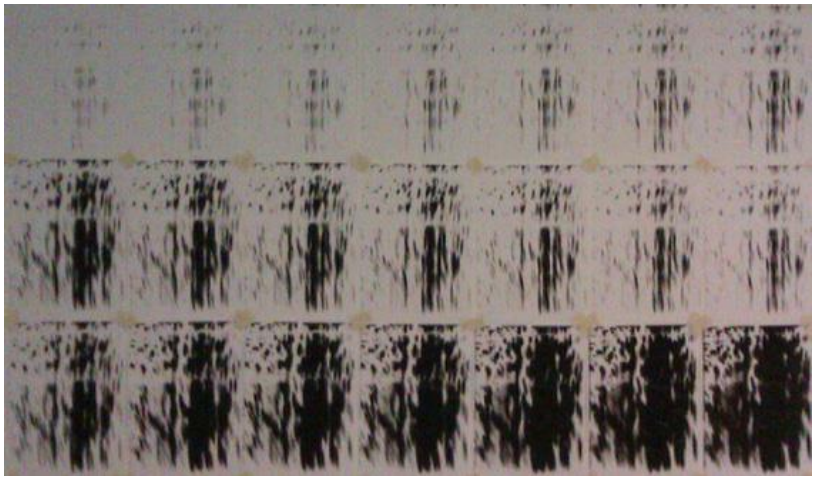
Urban and environmental sciences: the challenges of `big data: identifying novel ways to reuse existing data and extracting meaningful information (Wood, 2013)

Further research directions



Commonsense cognition of geospatial dynamics: bridging the gap between geography, AI and cognitive science i.e. better integration between data structures, algebra, and cognitive interpretation (Bhatt and Wallgrün, 2014)

Further research directions



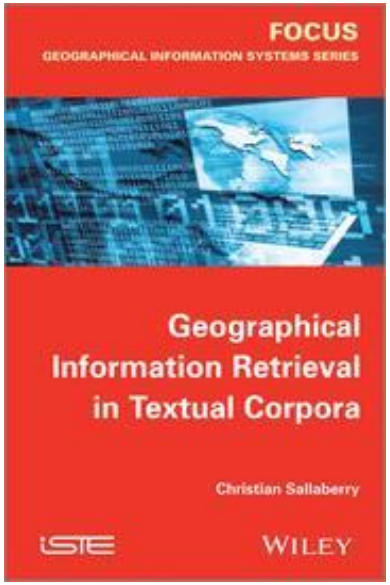
Relating space, time, and granularity (Stell, 2013)

http://www.johnstell.com/

Further research directions

The representation of **life trajectories** (e.g., movement paths of individuals over space-time) and the development of novel conceptual and computational frameworks continue to be an active research area (Vandersmissen et al., 2009)

Further research directions



Information retrieval & human interactions: new theories and rule-based reasoning mechanisms for extracting spatio-temporal event information from unstructured text documents (on the web) (Wang and Stewart, 2013)

Further research directions

Manipulation of spatiotemporal data at different levels of hierarchy, complementary visions of time and appropriate computational data structures and algorithms to represent them (Yuan 2008)

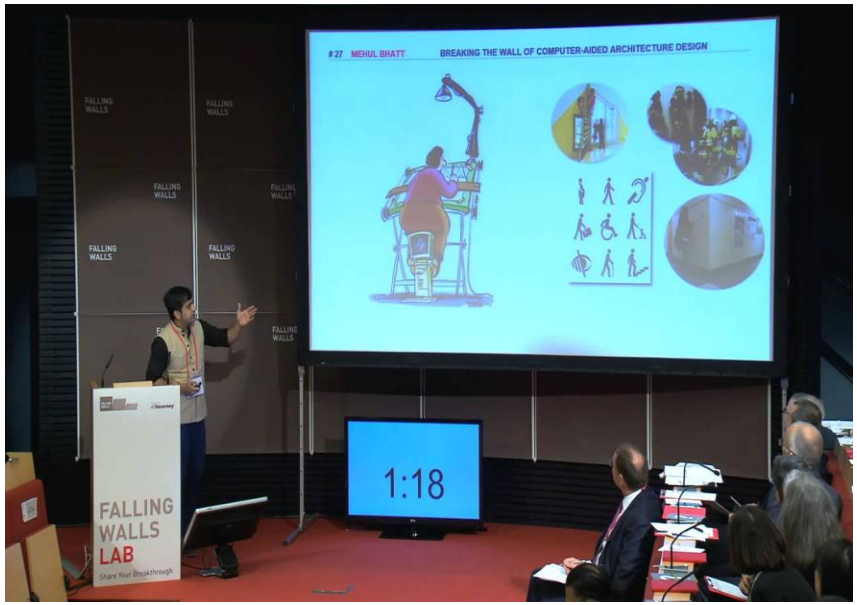
Further research directions

Advanced formal mechanisms to reason about geographic events and processes while integrating the concept of vagueness (Campelo and Bennett, 2013)

Further research directions

Discovering order in chaos by deriving spatio-temporal data on the fly. Identification of novel interacting reasoning facilities that can be applied to unstructured geographical data sources (Stock et al., this special issue)

Further research directions



Holistic spatial design: People-centered spatial design principles, indoor and architectural spaces where holistic design approaches can be combined with spatial reasoning capabilities (Bhatt et al., 2014)

More at https://www.youtube.com/watch?v=98chV4T1QDo

Some final comments…

from you ?

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